

2. Mercury absorbs oxygen in a similar manner.
3. In all cases the absorption relative to the electricity increases as the pressure decreases.
4. The gases probably assume active modifications under the influence of the electric discharge. This supposition is strengthened by the observation that the known active modification of nitrogen is absorbed when passed over the alloy.
5. The greater absorption, when the metals are used as the cathode, is due probably to the combination of the positive rays with the metal.

In conclusion, I wish to express my gratitude to Prof. R. J. Strutt, F.R.S., at whose suggestion the above investigation was undertaken, for his kind help and interest throughout the course of the research.

Photographic Analysis of Explosions in the Magnetic Field.

By Prof. HAROLD B. DIXON, F.R.S., C. CAMPBELL, M.Sc., and W. E. SLATER, B.Sc.

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[PLATES 5-8.]

Introductory.

In a discussion on Gaseous Combustion with particular reference to explosions, at the British Association Meeting at Sheffield, 1910, Sir J. J. Thomson called attention to the fact that combustion is concerned not only with atoms and molecules, but also with electrons moving with very high velocities. In the "surface combustions" studied by Prof. Bone it appeared probable that the streams of electrons known to be emitted by incandescent surfaces promoted combustion by electrifying the contiguous layers of gas, and the great rapidity of combustion in the explosion-wave might be due to the molecules at the moment of combustion sending out electrons with very high velocities. These may precede the explosion-wave and prepare the way for it by ionising the gas. But the motion of the ions can be stopped at once by means of a transverse magnetic field, in which they curl up and are caused to revolve in small circles. He therefore thought it would be of very great interest if Prof. Dixon would repeat his experiments on the photo-

graphy of the explosion-wave under such conditions as to determine whether the form of the wave could be modified by a magnetic field.

He further suggested that the phenomena of the damping of the velocity of electrons and the initiation of chemical change by small quantities of moisture might be closely related.

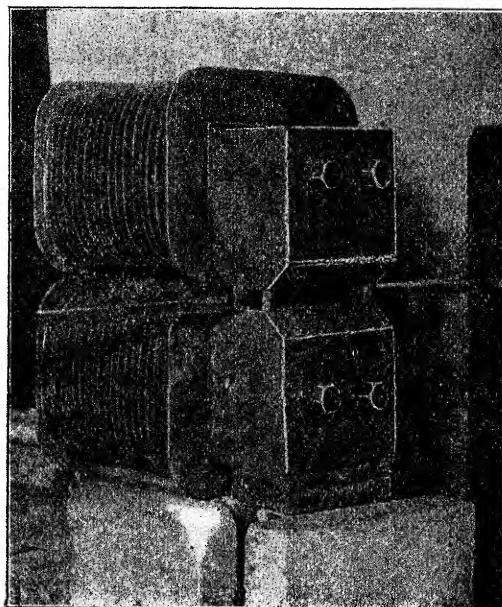
Sir J. J. Thomson's suggestion, the importance of which was emphasised by other physicists, led us to make several attempts to detect the effect of a magnetic field on the propagation of an explosion-wave. No effect could be detected with a short but intense field, or with a more extended but less intense field. But we were unwilling to publish negative results until we had experimented with a more powerful magnet. Then by the kindness of Sir Ernest Rutherford we were allowed the use of one of the two new magnets he constructed last year for the very purpose we had in view—that of deflecting electrons of high velocity.

This magnet had a longer and more intense field than either of the two we had previously used.

Description of Magnets.

Three series of experiments with three different electromagnets were carried out.

In the first series the magnet used was of a moderate size, being capable of taking a voltage of 100 and a current of 15 ampères. The field was concentrated by using very narrow pole-pieces, so that, although very intense, it



only covered about 3 cm. of the explosion tube. With a gap of 2 cm. between the poles, the intensity of the field obtained was about 8000 gauss.

The magnet used in the second series was similar in size, but with much larger pole-pieces, the field being spread out over about 40 sq. cm. The field obtained was therefore much less intense but more extended than with the first magnet. With a voltage of 60, a current of 10 ampères and a gap of 2 cm. between the poles, a field of 1500 gauss was obtained.

The magnet used in the third series was much more powerful than either of the above. The core was of the softest iron procurable, and of very high permeability. Each arm of the core carried a bobbin of brass with 1500 turns of thick copper wire, making a total for the entire magnet of over 3000 turns.

The pole-pieces, which were fixed in position by means of the large iron bolts as shown, were cut from rectangular blocks of soft iron of measurements 10 cm. wide, 16.5 cm. deep and 17 cm. long. Each pole-piece was bevelled along one side, so that the field was concentrated between two surfaces of 5 cm. $\times$ 17 cm. The gap used was about 2 cm. Under these conditions, and with an E.M.F. of 100 volts and a current of 7 ampères the intensity of the field was found by means of a fluxmeter to be 10,000 gauss. Through 17 cm. of this field the explosion was made to travel.

To obtain a practical test of the efficiency of the magnet in deflecting a stream of electrons, its effect on the β -rays from radium was tried. A tube of radium bromide was placed at one end of the field and a barium platino-cyanide screen at the other. Before turning on the current, the phosphorescence produced by the rays was easily visible, but immediately the magnet was made, it disappeared. The experiment was repeated with the screen at a distance of 10 mm. from the radium. Again every ray was taken out. Finally, by bending the screen into a half-tube and by placing the radium in the axis of it, it was found that all the rays were so deflected that no point on screen more than 2 mm. in front of the radium was affected.

Arrangement of the Magnets.

The magnets were arranged similarly to the one shown in the photograph, one pole-piece standing directly above the other in such a way as to allow the explosion tube to pass horizontally between the two. In each case the distance between the pole-pieces was 2 cm., being just sufficient to admit the glass tube.

With the two smaller magnets, thin wooden props were placed at each corner of the poles to act as reference marks.

In the case of the third magnet, small brass pillars were substituted for the

wooden props, to serve the purpose of supports, the iron bolts being insufficient to withstand the mutual attraction of the poles: These pillars appear in the photographs as two dark vertical bands, the thinner one being the nearer to the starting point of the detonation wave.

The height of the magnets was adjusted so that the part of the tube running between the poles was at right angles with the camera, and in the same horizontal plane.

The distance between the tube and the camera was such that about 10 cm. of the tube on each side of the poles should appear on the photograph.

Arrangement of Tubes, etc.

The tube in which the explosion was made to travel consisted of a lead pipe, of length 130 cm. and internal bore 1.2 cm. At one end of this was a brass ferrule into which was fixed by means of Faraday cement a strong glass tube of length 68 cm. and internal bore 1.2 cm. At the other end was the sparking arrangement (a glass firing-piece carrying two platinum terminals) and a brass tap through which the tube was filled. By this means time was allowed for the explosion to set up the detonation wave before reaching the magnetic field.

In the experiments on the initiation of the flame, the platinum terminals were fused into the glass tube in which the explosion was photographed, the spark being passed in some cases between the poles of the magnet, in others about 1 inch beyond them.

In all cases the mixture was fired by a discharge from a Ruhmkorff coil, which was started by means of a switch near the camera.

The Photographic Apparatus.

The camera was similar to the one used in previous experiments on the photographic analysis of explosions.

It consisted essentially of a stout light-proof box fitted with an adjustable lens which could be focussed on to a rapidly revolving wheel carrying the film. This wheel was 1 metre in circumference and could be rotated by means of suitable gearing at a speed of about 80 revolutions per second.

Eastman's N.C. films were found to be the most suitable for the purpose.

Description of an Experiment.

The method of carrying out an experiment was as follows:—

The camera having been focussed on the portion of the tube passing between the magnetic poles, the tube was swept out and filled with the previously prepared mixture, and a cork inserted in the free end of the glass tube.

In experiments with the less violent mixtures such as $2\text{CO} + \text{O}_2$ and $\text{H}_2 + 2\text{O}_2$, the cork was firmly fixed but with the more violent mixtures it was inserted loosely and allowed to be blown out.

The room was then darkened and the film fixed on the wheel and rotated. The speed of the wheel was not determined accurately, but a rough measurement showed that in all these experiments the wheel performed about 40 revolutions per second, corresponding with a velocity for the film of 40 metres per second. As soon as the wheel was rotating uniformly, the current was switched on to the magnet and the mixture fired.

The experiment was then repeated under exactly the same conditions, except that no current was sent through the magnet. By this means pictures were obtained of explosions of the same mixture with and without the magnet, other conditions being the same. These could then be compared and any difference between them noted. The films were developed and fixed in the usual manner.

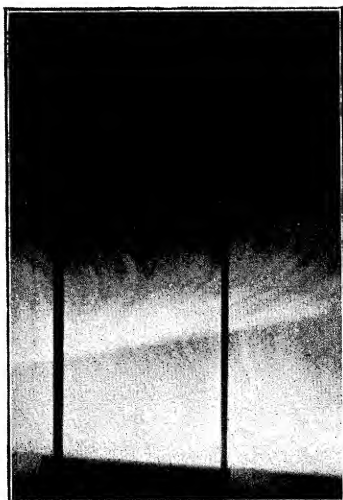
Description of the Photographs (Plates 5-8).

The photographs reproduced show the movements of the flames of different gaseous mixtures analysed by the rotation of the film.

(1) The explosion-waves in the following mixtures were photographed as they entered, traversed and emerged from the magnetic field, and again when they travelled through the same tube without the magnet being made:—

- α.* Cyanogen and oxygen with different proportions of nitrogen.
- β.* Hydrogen and oxygen in different proportions.
- γ.* Acetylene and oxygen.
- δ.* Carbon disulphide and oxygen.
- ε.* Carbon monoxide and oxygen.

In Photographs 1 and 2 the explosion-waves in equal volumes of cyanogen, oxygen, and nitrogen are shown. The wave travelling from right to left at a uniform velocity makes a straight inclined line at the bottom of the picture, the inclination depending on the horizontal velocity of the image of the explosion-wave and on the vertical velocity of the film. The entrance to the magnetic field is marked by the first vertical dark line on the photograph made by the small brass pillar (which helps to separate the magnets) obscuring the light in the tube behind it. The flame is seen to continue in the same straight line and with the same brightness as before, and therefore with the same velocity and intensity through the magnetic field, and after passing the second vertical dark line, made by the corresponding brass pillar at the further end of the magnet, to continue its course without alteration. The inclined line stretching from left to right above the first is



1

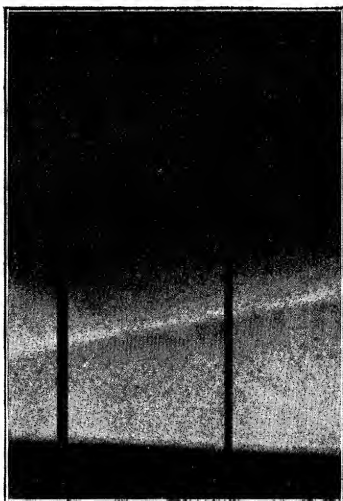
Magnet on.



2

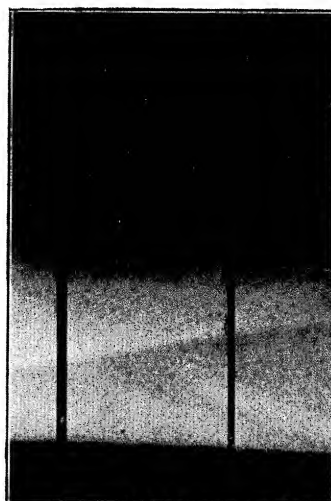
Magnet off.

PHOTOS. 1 AND 2.—Explosion-wave in Mixture $C_2N_2 + O_2 + N_2$.



3

Magnet on.



4

Magnet off.

PHOTOS. 3 AND 4.—Explosion-wave in Electrolytic Gas.



5

Magnet on.



6

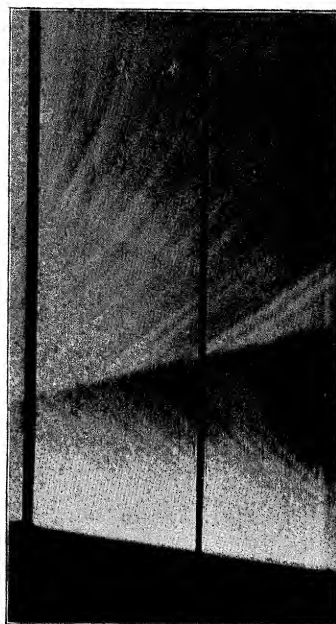
Magnet off.

PHOTOS. 5 AND 6.—Explosion-wave in Mixture $C_2H_2+5O_2$.



7

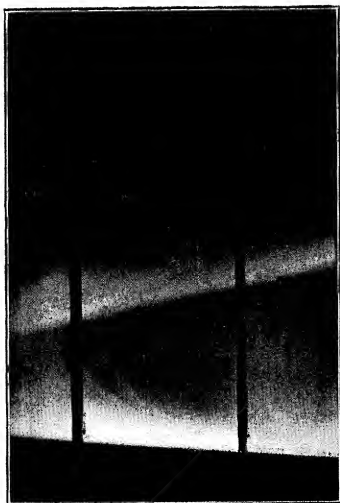
Magnet on.



8

Magnet off.

PHOTOS. 7 AND 8.—Explosion-wave in Mixture CS_2+3O_2 .



9

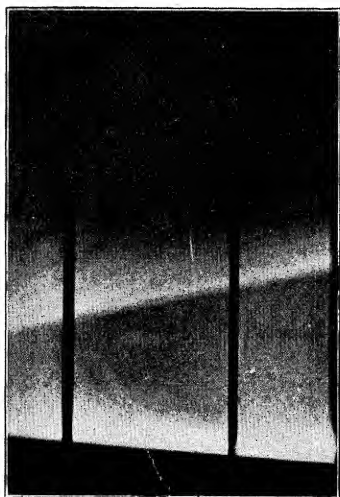
Magnet on.



10

Magnet off.

PHOTOS. 9 AND 10.—Explosion-wave in Mixture $2\text{CO} + \text{O}_2$.



11

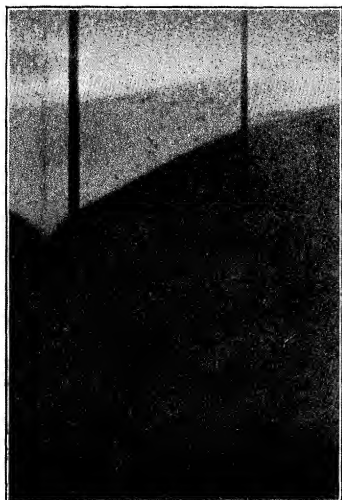
Moist.—Magnet on.



12

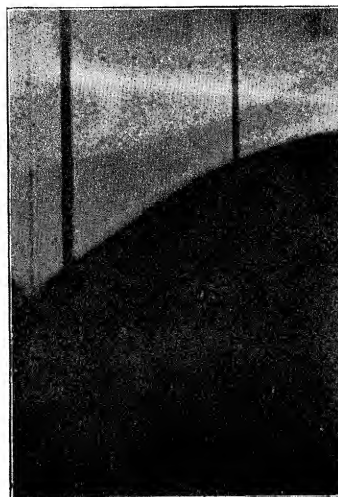
Dry.—Magnet on.

PHOTOS. 11 AND 12.—Explosion-wave in Moist and Dry Mixture $2\text{CO} + \text{O}_2$.



13

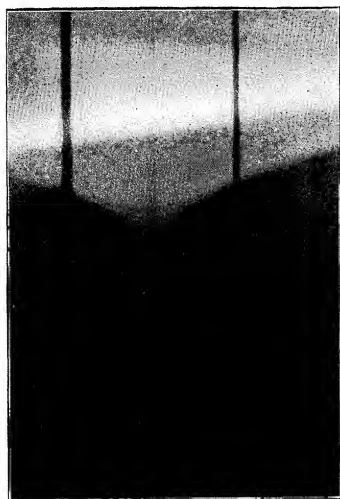
Magnet on.



14

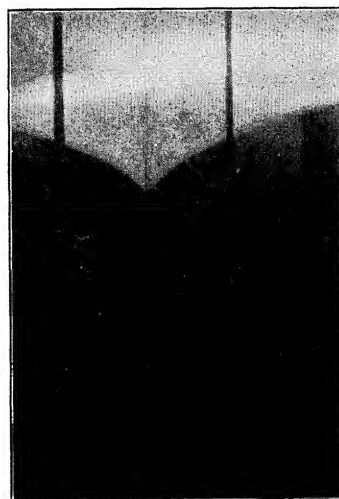
Magnet off.

PHOTOS. 13 AND 14.—Spark passed outside Poles in Mixture $C_2H_2 + 5O_2$.



15

Magnet on.



16

Magnet off.

PHOTOS. 15 AND 16.—Spark passed in Centre of Field in Mixture $C_2H_2 + 5O_2$.

caused by the reflection from the cork at the end of the tube. This reflected wave (travelling, of course, more slowly than the explosion wave) appears also to be unaffected by the magnetic field. The companion photograph shows the progress of the explosion wave and the return of the reflected wave in the same mixture without the magnet being made. No difference due to the magnetic field can be detected.

Photographs 3 and 4 show the explosion-waves in electrolytic gas. The flames travel, as before, from right to left, and the reflected waves return, later, from left to right. No difference due to the magnetic field can be detected.

Photographs 5 and 6, acetylene and oxygen, and 7 and 8, carbon disulphide and oxygen, show more detail, as the flames are brighter and more prolonged. In each case a second reflected wave, travelling in the same direction as the original explosion wave (from right to left), is visible high up in the photographs. The magnetic field has no visible influence.

Photographs 9 and 10 show the explosion-waves in carbon monoxide and oxygen. In this mixture—where water vapour is necessary for the propagation of the explosion and a wider scope for the action of electrons might be presumed—there is still nothing which can be attributed to the magnetic field. Comparative experiments with the moist and dried gases—the dried mixture having stood over oil of vitriol—showed no difference as the flames traversed the magnetic field. (Photographs 11 and 12.)

(2) Lastly, the effect of the magnetic field on the initiatory phases of explosion flames was studied. The photographs reproduced show (13 and 14) the flame in acetylene and oxygen initiated by a spark just outside (to the left) of the magnetic field. The flame as it spreads to the right enters and passes through the field, its acceleration being unaffected by the magnet. The explosion-wave is not set up before the flame has passed beyond the range of the photograph.

Photographs 15 and 16 show the same mixture (acetylene and oxygen) fired by a spark in the centre of the picture between the magnetic poles. The flames spread in the same way whether the magnet is on or off. The central (faint) perpendicular band is due to distortion of the glass tube where the platinum wire is fused in.

Since the powerful magnetic field employed produced no visible effect with any gas mixture, and since the mechanism of a compression-wave (liberating the chemical energy as it goes along) accounts in a reasonable way for the phenomena of gas explosions, we see no evidence that convinces us that the velocity of the explosion-wave is due to the ionising action of electrons.





1

Magnet on.



2

Magnet off.

PHOTOS. 1 AND 2.—Explosion-wave in Mixture $C_2N_2 + O_2 + N_2$



3

Magnet on.



4

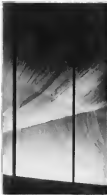
Magnet off.

FIGURES 3 AND 4.—Explosion-wave in Electrolytic Gas.



5

Magnet on.



6

Magnet off.

PHOTOS. 5 AND 6.—Explosion-wave in Mixture $C_2H_2 + 5O_2$



7

Magnet on.



8

Magnet off.

PHOTOS. 7 AND 8.—Explosion-wave in Mixture $\text{CS}_2 + 3\text{O}_2$



9

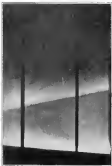
Magnet on.



10

Magnet off.

PHOTOS. 9 AND 10.—Explosion-wave in Mixture 200 + O_2 .



11

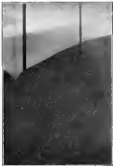
Moist.—Magnet on.



12

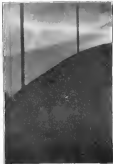
Dry.—Magnet on.

PHOTOS 11 AND 12.—Explosion-wave in Moist and Dry Mixture $2\text{CO} + \text{O}_2$.



13

Magnet on.



14

Magnet off.

FIGURES 13 AND 14.—Spark passed outside Poles in Mixture $C_2H_2 + 5O_2$



15

Magnet on.



16

Magnet off.

PHOTOS. 15 AND 16.—Spark passed in Centre of Field in Mixture $C_2H_2 + 5O_2$